Bulletin 920 November 1958

* Chemical, Cultural and Mechanical Control of the

* Pink Bollworm

in cooperation with the
UNITED STATES DEPARTMENT OF AGRICULTURE

TEXAS AGRICULTURAL EXPERIMENT STATION

R. D. LEWIS, DIRECTOR, COLLEGE STATION, TEXAS

SUMMARY

This bulletin summarizes much of the research conducted on the pink bollworm by the Texas Agricultural Experiment Station during 1953-57.

A review of the life and seasonal history of the pink bollworm is presented along with descriptions of damage resulting to cotton from attacks by this pest. Spring emergence records for several areas of the State are given. Data presented for the College Station area indicated that peak emergence of pink bollworm moths occurred from late May through early June. Emergence continued into August in every year records were taken except 1956.

Cage tests indicated that pink bollworm infestation levels up to about 50 percent infested bolls caused relatively small decreases in the value of the cotton produced, provided the infested bolls averaged less than 2 larvae per boll. Field experiments indicated there was a trend toward a lower dollar-per-acre return with an increase in infestation.

Guthion and DDT were the most effective insecticides for controlling the pink bollworm in field and laboratory tests. Control of the pink bollworm by insecticides was done by adult mortality, reduction in oviposition and death of developing embryos and newly hatched larvae.

The use of defoliants delayed the build-up of pink bollworm infestation 2 to 3 weeks following defoliation.

Approximately 150 varieties or species of cotton have been screened for pink bollworm resistance. Three species have been found which possess properties detrimental to pink bollworm larvae. This was evidenced by a reduction in the number of surviving larvae on Gossypium thurberi and a G. tomentosum x G. hirsutum (Stoneville 2B) cross and by a lengthening of the larval developmental period on G. arboreum.

Mortalities of approximately 90 percent of the larvae remaining in the field after harvest were obtained by modified stalk shredders and ensilage harvesters.

Different spray nozzle arrangements and gallonages of spray per acre were tested. One nozzle per row was as effective as any arrangement tested. There were no appreciable differences in control with gallonages of spray ranging from 2 to 30 gallons per acre.

ACKNOWLEDGMENTS

Much of the data reported herein was obtained from experiments conducted in entomology during 1953-57 by W. J. Magee and from experiments in agricultural engineering during 1953-56 by M. G. Davenport.

Credit for entomological investigations reported in this bulletin also is due J. R. Brazzel, D. F. Martin and R. K. Williams for their data on spring emergence, host plant resistance and chemical control. J. R. Brazzel and J. C. Gaines also contributed data to the section on yield and quality losses resulting from pink bollworm infestations.

These investigations were conducted cooperatively by the Texas Agricultural Experiment Station and the Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture. A portion of them was contributory to southern regional project S-37, "Pink Bollworm Control."

CONTENTS

Chemical, Cultural and Mechanical Control of the Pink Bollworm

*Perry L. Adkisson, L. H. Wilkes and S. P. Johnson**

THE PINK BOLLWORM, *Pectinophora gossypiella* (Saund.) has long been of concern to farmers and entomologists across the cotton belt. In infested areas, the pink bollworm has caused serious reductions in the yield and quality of the affected cotton, and over the years has been one of the most destructive cotton insects. For example, in 1952 alone, the pink bollworm caused an estimated $28,000,000 loss in a 38-county area of South Texas (Anonymous, 1954).

Cultural, chemical and mechanical control methods are used to control insects. Until the advent of DDT, there were no effective chemical means for controlling the pink bollworms, therefore, farmers relied almost entirely on such measures as regulated planting, stalk shredding, early harvesting and by plowing under the cotton debris. These methods were not completely satisfactory and research for better methods of controlling the pink bollworm were continued.

This bulletin summarizes much of the work conducted during 1953-57 by the Texas Agricultural Experiment Station in search of better ways to combat the pink bollworm.

LIFE HISTORY

Detailed information pertaining to the life and seasonal history of the pink bollworm has been published by several entomologists (Ohlendorf, 1926; Fenton, 1928; Fenton and Owen, 1931, 1953; Owen and Calhoun, 1932; Chapman and Hughes, 1941; Fife, 1956; and Lukefahr and Griffin, 1956, 1957). The pink bollworm undergoes four developmental stages—egg, larva, pupa and adult, Figure 1—completing the life cycle in 25 to 30 days in midsummer. There may be as many as six generations in a year.

The adult is a small grayish brown moth. The adults are most active at night and seek shelter during the day, and thus, are seldom seen in an infested field. A female may lay 50 to 300 eggs over a period of about 8 days.

The eggs may be deposited singly or in masses on vegetative or fruiting parts of the cotton plant. The preferred oviposition site is between the calyx and the boll carpel. Eggs normally hatch in 4 to 5 days.

The larva is a small caterpillar which may attain a length of about one-half inch when full grown. In the early instars, the larva is whitish in color and usually transforms to a shade of pink by the time it attains full growth. It is this pinkish color of the mature larva which suggests the common name of the insect. The larvae feed inside the squares or bolls for 10 to 14 days. They then usually leave the fruiting parts of the cotton plants and pupate in the soil. These are termed "short cycle" larvae and give rise to the adults of the current year. Many larvae do not pupate immediately on completion of the feeding period, but remain inside the boll. These are termed dia-

*Respectively, associate professor, Department of Entomology; associate professor, Department of Agricultural Engineering, and assistant professor, Department of Plant Physiology and Pathology.

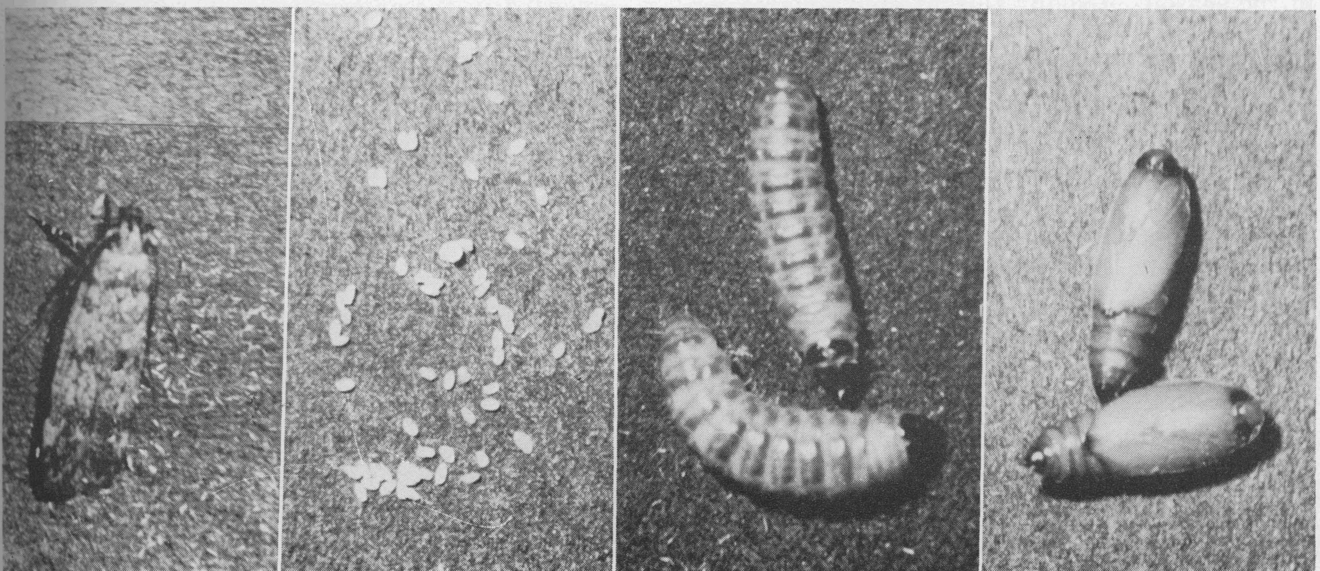

Figure 1. Adult, egg, larvae and pupal stages of the pink bollworm.

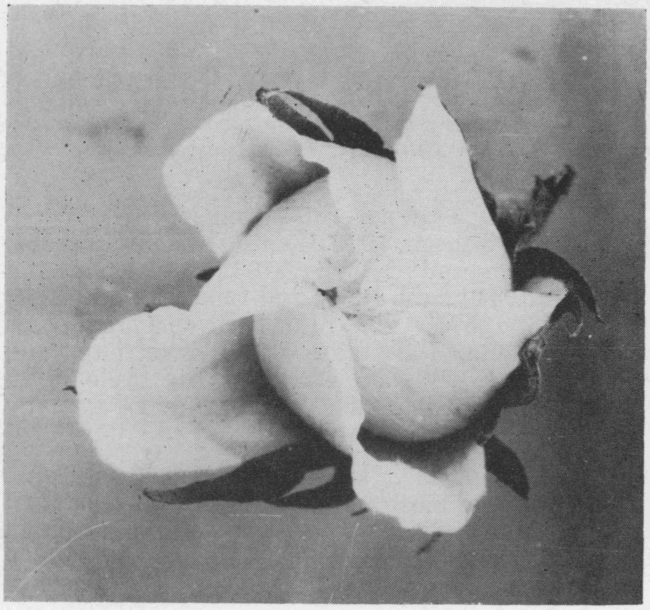

Figure 2. Rosetted bloom which resulted from pink bollworm infestation.

pause or "long cycle" larvae since they are in a quiescent condition of arrested growth. It is the diapausing larvae which survive the winter and give rise to the first generation of the following season. Some diapausing larvae may not pupate until in their second year of life. Most of the diapausing larvae pass the winter in the bolls in which they developed; however, some may overwinter in cottonseed, in trash in the field or at gins, or in cracks in the soil.

Pupation generally occurs in the soil and about 8 days are required to complete transformation to the adult stage

NATURE OF DAMAGE

The pink bollworm may attack squares early in the season. Usually the infested squares continue growth and produce blooms. Infested blooms will have the petals tied together with a silken thread and are commonly termed "rosetted" blooms, Figure 2. They do not open normally. This is one of the first signs of pink bollworm infestation.

Bolls are preferred later in the season. The larvae gain entrance into bolls by burrowing or tunneling through the boll wall until they reach the lint. The entrance holes left by the larvae are small, but can be detected on close examination with the naked eye. Once inside the boll, the larvae may burrow through the lint searching out the seed. This burrowing often causes staining of the lint and may weaken the fiber. During heavy infestations, many bolls that might otherwise have been harvested are rendered unpickable as the result of pink bollworm attack. The damage done contributes to losses in yield. This is especially true if the crop is to be harvested with mechanical pickers. Figure 3 shows various degrees of damage to several bolls.

Pink bollworm larvae also will damage the seed, reducing their weight, vitality and oil content.

Increased incidence of boll rots resulting from pink bollworm infestations also may contribute to further yield and quality losses. Many larvae on completion of development will cut emergence holes to leave the bolls for pupation. These emergence holes, Figure 4, similar in size to a "shot hole," may provide an avenue for the entrance of boll rot organisms under certain conditions.

Several methods of determining pink bollworm infestations were used. Among these were the number of rosetted blooms per acre, percentage of bolls infested, number of larvae per boll and number of mines per boll. All of these methods were used during these investigations and are reported in the appropriate tables.

Figure 3. Degrees of pink bollworm damage to cotton bolls ranging from nearly complete destruction to no damage.

SPRING EMERGENCE

Records of emergence of overwintered pink bollworms have been taken by state and federal workers for many years at various locations in Texas. Generally, these records were obtained by counts of the number of moths emerging from infested cotton placed on the soil surface underneath pyramidal emergence cages during the fall of the year preceding each record. These cages were fitted with small collection tubes which trapped the moths as they emerged. The trapped moths were counted periodically until emergence was complete.

Published records indicate that in the Presidio area peak emergence may occur from late April until mid-June, but emergence may continue to mid-August (Owen and Calhoun, 1932). In the Waco area, emergence may take place anytime from mid-March to late August. However, in the years for which records were taken, up to 67 percent of the total pink bollworm emergence was completed before cotton began to bloom (Fife,, 1956; Fife, *et al* 1957). Moths may emerge every month in the Lower Rio Grande Valley; however, only those moths emerging after March 15 are able to infest cotton of the current year. Several years' data for this area indicate that 65 to 85 percent of the total emergence normally occurs during May; but emergence may extend into August (Noble, 1955).

Emergence records have been taken of the pink bollworm at College Station since 1954, Figure 5, Table 1. These records are based on the numbers of moths emerging in the spring from infested cotton which had been held under field conditions on the soil surface beneath emergence cages since the previous fall. Records indicate that survival of long-cycle pink bollworm larvae in the College Station area ranged from 9 to 93 percent. Peak emergence coincides with the normal early fruiting period of cotton, since most of the moths emerged from late May through mid-June. However, in all years except 1956, there was some emergence after June and moths continued to appear in the cages to the latter part of August. The regulated cotton planting period in the College Station area extends from March 20 to May 31, which indicates that fruiting cotton will be available to a high percentage of emerging moths.

The relationship of temperature, rainfall and emergence of wintering pink bollworm larvae, as pointed out by Brazzel and Martin (1958), is shown in Figure 5. Their results indicate that average temperatures below 70° F. caused an immediate reduction in the emergence of pink bollworm moths. Rainfall also had an effect since moth emergence increased within 10 to 14 days following half an inch or more of rain. Moth emergence dropped sharply following 2 or 3 weeks of dry weather.

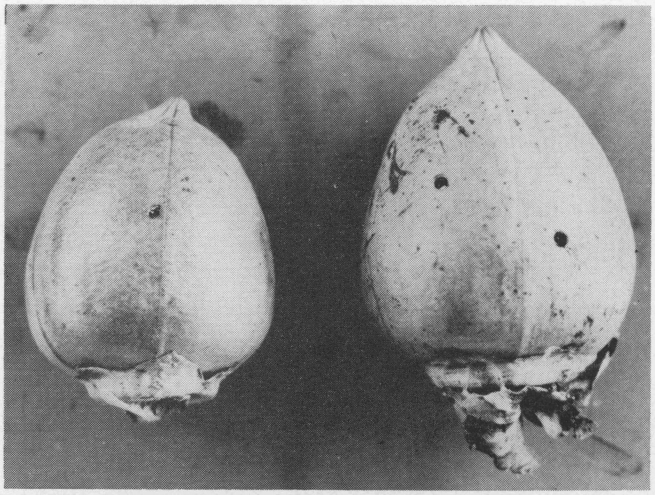

Figure 4. Pink bollworm emergence holes from infested bolls.

LOSSES IN YIELD AND QUALITY

Many reports have been made on the damage of pink bollworm infestations to the yield and quality of cotton. In some foreign countries, the insect has been credited with tremendous losses, and in 1952 caused heavy losses to the crop in parts of Texas (Anonymous, 1954).

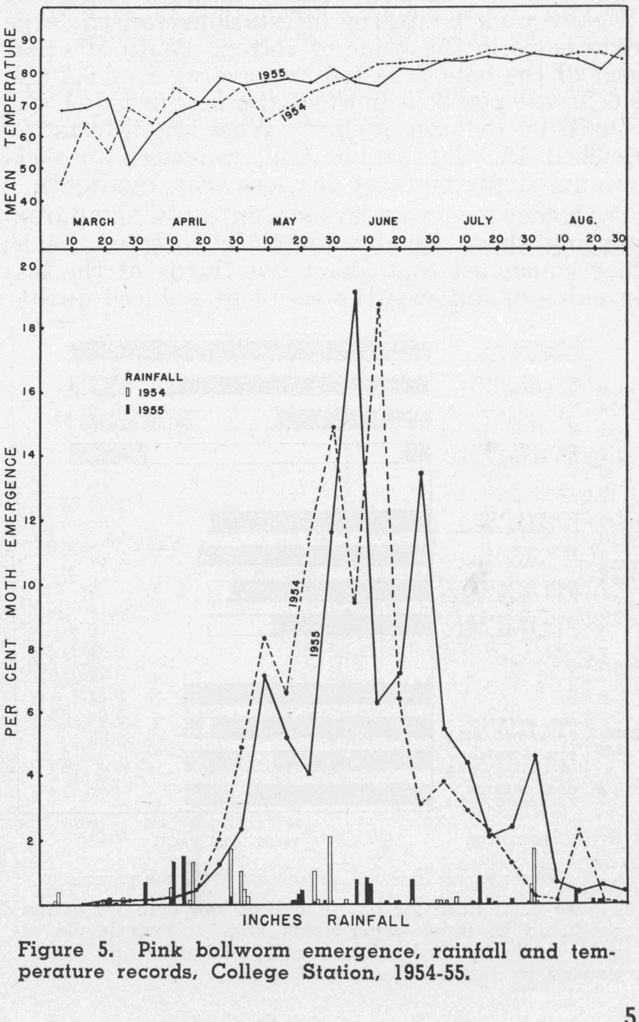

Figure 5. Pink bollworm emergence, rainfall and temperature records, College Station, 1954-55.

TABLE 1. WINTER SURVIVAL OF LARVAE AND TIME OF EMERGENCE OF ADULT PINK BOLLWORMS AT COLLEGE STATION 1954-57

Year	Estimated number of larvae caged	Number of adults recovered	% survival	% recovery		
				Before June 1	June 1-30	After June 30
1953-54	3,000	1,973	65.8	50.4	38.1	11.5
1954-55	11,592	10,830	93.4	32.9	42.9	24.4
1955-56	11,340	8,185	72.2	17.7	45.1	37.2
1956-57	8,220	761	9.2	91.2	8.8	0

Because the losses were determined mostly from field experiments which often were complicated by the presence of other pests, such as the boll weevil, *Anthonomus grandis* Boh., a series of cage tests were conducted to better evaluate the losses resulting from certain levels of infestation. Much of the work by this Station has been reported previously (Brazzel and Gaines, 1956; 1957).

Caged plots, 1/200 acre in size, were used in which the desired levels of infestation were obtained by periodic pink bollworm releases. Periodic applications of DDT were made to maintain infestations at desired levels. Infestations of other insects were kept at a minimum since they were prevented from entering the plots by screen cages.

Results of work in 1955-56 are shown in Figures 6 and 7 taken from a report by Brazzel and Gaines (1957). These authors reported: "Heavy pink bollworm infestations caused large reductions in the value of cotton. With 100 percent of the bolls infested and averages of 6.4 and 9.6 larvae per boll, most of the loss in value was caused by reduced quality. When the infestation reached 12.9 larvae per boll, reduction in yield accounted for more of the loss than quality."

Under moderate levels of infestation, approximating those usually found in infested fields, they concluded that about two-thirds of the loss in value of lint was the result of reduced quality when the cotton was snapped. Lint-yield losses occurred, but no quality losses were evident for hand-picked cotton. Losses in value of seed was about equally divided between reduced yields and quality.

These results indicate that pink bollworm infestation levels up to about 50 percent infested bolls and less than 2 larvae per boll cause relatively small decreases in the value of the cotton produced under the conditions of these experiments. However, these authors emphasized that these experiments were conducted under extremely dry weather conditions which may have minimized pink bollworm damage to the cotton. Had there been at least normal rainfall, it is possible that further losses in yield and quality would have occurred as the result of increased boll rots. All the cotton produced in these experiments was low grade, with the best samples taken from the insect-free check grading good ordinary to strict good ordinary. Had the cotton in the check been a higher grade, it is possible that the yield and quality losses resulting from the pink bollworm infestations would have been even more obvious. There was a trend towards lowered yields with an increase in infestation.

It has been thought that in wet seasons the pink bollworm may further reduce yield and qual-

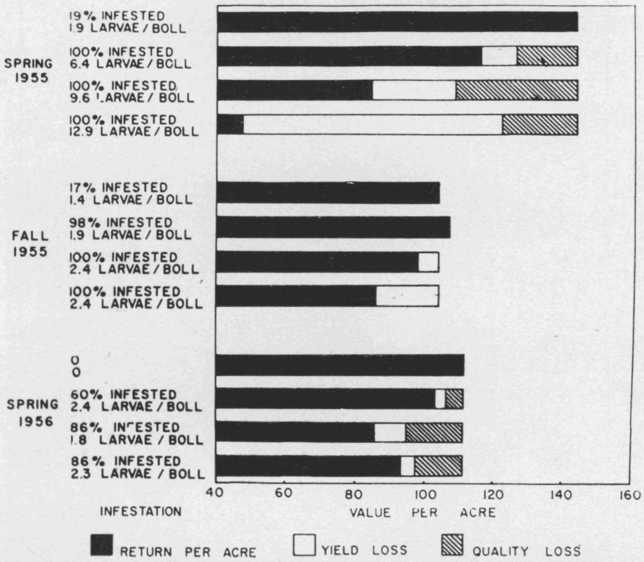

Figure 6. Return for lint in dollars per acre for cotton produced in three experiments with various levels of pink bollworm infestation, and evaluation of losses caused by reduced yield and quality.

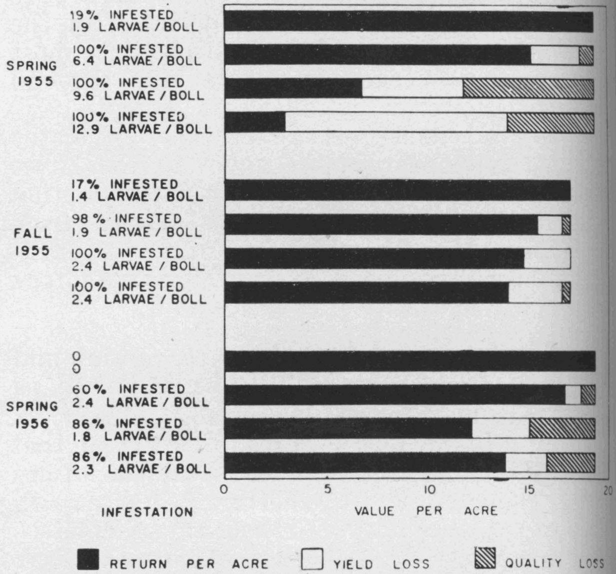

Figure 7. Return for cottonseed in dollars per acre for cotton produced in three experiments with various levels of pink bollworm infestation, and evaluation of losses caused by reduced yield and quality.

ity by contributing to the incidence of boll rots. Work at this Station under laboratory conditions has shown that pink bollworm entrance holes into the bolls evidently were not a factor in contributing to boll rots (Brazzel, 1955); however, it is believed generally that pink bollworm emergence holes can contribute to increased incidence of boll rots. Studies along these lines and cage studies of the effect of different levels of pink bollworm infestations on the value of cotton lint grown under sprinkler irrigation are beng continued to gain more knowledge on the relationship of infestation to boll rots and cotton yield and quality.

A field experiment also was conducted near College Station in 1955 to evaluate the effect of different infestation levels of pink bollworm on cotton quality and yield.

These tests used 0.1 acre randomized, replicated plots. Four levels of initial infestation, plus an untreated check were the designated treatments. Each treatment was replicated five times in a latin square design. Treatments were (1) check—seven applications of endrin; (2) 10 percent initial infestation—seven applications of dieldrin-DDT (1-6) mixture; (3) 20 percent initial infestation—one application of endrin followed by six of dieldrin-DDT (1-6) mixture; (4) 40 percent initial infestation—three applications of endrin followed by four of dieldrin-DDT (1-6) mixture; and (5) 80 percent initial infestation—five applications of endrin followed by one of dieldrin-DDT (1-6) mixture. The endrin was applied at the rate of 0.4 pound of toxicant per acre at each application, and the dieldrin-DDT (1-6) mixture at 0.4 pound of actual dieldrin, plus 3.0 pounds of DDT per acre at each application. All the insecticides were applied as sprays prepared from emulsifiable concentrates. Insecticidal applications were begun on July 5 and continued at weekly intervals to August 16. The sprays were applied with a high clearance sprayer at 60 p. s. i. traveling at a speed of 3.75 m. p. h. Damaging infestation of insects other than the pink bollworm did not develop.

Results are presented in Table 2. Reduction in yield resulting from the higher infestation levels of the check, 40 percent, and 80 percent initial infestation treatments were statistically significant when compared with the two lower infestation levels of 10 and 20 percent. Samples of lint taken from the various treatments indicated lower grades as a result of the higher infestations. There was little difference in lint percentage among the treatments. The yields and cents per pound lint values indicate a trend towards a lower dollar per acre return with an increase in infestation.

There also was a trend toward more bad seed per 100 gram sample as the levels of infestation became higher. Seed damage apparently was equally distributed over the plant, as indicated by data obtained from samples taken from the top, middle and bottom portions of the plant. Germination tests indicated little difference in viability of intact seed taken from the various infestation levels. These data are presented in

TABLE 2. EVALUATION OF SEVERAL INFESTATION LEVELS ON LINT YIELD AND QUALITY, 1955

Date	Check	Initial infestation			
		10%	20%	40%	80%
		Average percentage infested bolls			
June 30	10.4	12.6[1]	10.4	12.0	14.6
July 9	23.2	17.0	21.6[1]	35.0	22.2
July 14	25.6	22.4	24.8	35.6	28.6
July 22	43.2	22.8	43.8	34.0[1]	27.0
July 28	37.0	16.6	28.8	30.8	43.2
August 4	47.4	24.6	29.8	45.0	46.6
August 11	81.4	22.8	27.0	49.0	77.0[1]
August 19	90.0	45.6	39.6	52.2	89.0
Average	44.8	23.1	28.2	36.7	43.5
		Average number of mines per 100 bolls			
June 30	21.8	21.8	16.2	18.2	27.8
July 9	42.2	27.2	44.8	96.5	50.5
July 14	48.4	40.8	43.4	62.6	55.6
July 22	69.4	34.2	97.0	56.8	40.6
July 28	55.0	25.4	47.8	53.4	75.6
August 4	80.2	34.6	37.6	88.0	74.6
August 11	284.6	43.8	41.8	101.0	267.9
August 19	452.0	84.2	66.2	112.6	392.4
Average	131.7	39.0	49.4	73.6	123.1
		Pounds of seed cotton per acre			
August 29	1500	1688	1636	1452	1436
		Sample grade			
	LMEW+	SLMEW	SLM	SLMEW	LMEW
		Staple length			
	15/16	15/16	15/16	31/32	29/32
		Value of lint, cents per pound			
	30.45	31.45	30.45	31.90	27.95

[1]DDT added to all applications made after this count.

TABLE 3. PERCENTAGE GOOD AND BAD SEED OBTAINED FROM 100 GRAM SEED SAMPLES TAKEN FROM VARIOUS INFESTATION LEVELS

Treatment	Portion of plant bolls taken	Number of seed		% bad seed	% germination of intact seed
		Good	Bad		
Check	Top	975	39	3.8	95.6
	Middle	805	24	2.9	94.8
	Bottom	795	12	1.5	95.4
	Total	2575	75	2.8	95.3
10% initial infestation	Top	900	3	0.3	96.3
	Middle	886	9	1.0	85.8
	Bottom	783	9	1.1	91.9
	Total	2569	21	0.8	91.5
20% initial infestation	Top	912	3	0.3	90.0
	Middle	800	30	3.6	95.0
	Bottom	769	25	3.1	92.6
	Total	2481	58	2.3	92.5
40% initial infestation	Top	867	33	3.7	80.0
	Middle	843	21	2.4	84.4
	Bottom	775	19	2.4	96.2
	Total	2485	73	2.9	86.8
80% initial infestation	Top	934	16	1.7	90.4
	Middle	862	12	1.4	91.9
	Bottom	767	53	6.5	83.7
	Total	2563	81	3.1	88.6

Table 3. Results obtained from the cage tests (Figure 7) suggest that under certain conditions seed losses may be greater than indicated by this experiment.

RESISTANT VARIETIES AND SPECIES

The development of a commercially accepted cotton variety resistant to pink pollworm attack has been the objective of a long-range breeding program initiated in 1954 at College Station. Investigations have included a search for a cotton possessing physiological resistance to pink bollworm and a search for any plant morphological characters which would influence the female moths to deposit more of their eggs on exposed parts of the plants rather than beneath the boll calyx. Preliminary phases of this work were reported in Station Bulletin 843 (Brazzel and Martin, 1956).

Approximately 150 varieties and species of cotton have been screened for resistance to pink bollworm attack. In the initial screening, the cotton was infested manually by placing a number of viable pink bollworm eggs on bolls of specific ages. The number of surviving larvae and number of days required for their developmental stages were the criteria used for screening. The varieties that appeared to possess some degree of resistance were then planted in 6 x 6 x 36-foot field cages and exposed to heavy pink bollworm infestations. These varieties were evaluated according to the number of larval entrance holes per boll, larvae recovered per boll, percentage bolls escaping injury and the number and location of eggs deposited on the plants of the different cottons. Three species were found which possessed properties detrimental to pink bollworm larvae. This was evidenced by a reduction in the number of surviving larvae on *Gossypium thurberi* and a *G. tomentosum* x *G. hirsutum* (Stoneville 2B) cross and by a lengthening of the larval developmental period on *G. arboreum*

This work was continued in 1956, as shown by the results reported in Table 4. Three stalks of each type of cotton tested were planted randomly in each of four large field cages. Bolls were tagged at 10-day intervals throughout the season, beginning when the first bolls were 10 days old. When the first bolls were 10 to 20 days old, 150 moths were released into each cage. After 10 days, these bolls were removed from the plants and another 150 moths released into each cage. This procedure was repeated until the end of the season.

The bolls were weighed and the number and location of larval entrance holes recorded. Records also were taken of the number of larvae per gram of boll to take boll size into consideration.

These tests indicated that Deltapine 15, Stoneville 2B and Texas 42 had the greatest number of damaged bolls, while the *G. tomentosum* x Stoneville 2B cross and *G. thurberi* had the fewest injured bolls. The other cottons were intermediate in this respect.

The most larvae per gram of boll were recovered from *G. thurberi* (a small-boll variety), Texas 42 and Z74275, and fewest from the *G. tomentosum* x Stoneville 2B cross.

The other approach to the problem was to investigate the influence of certain plant morphological characters on the oviposition sites select-

TABLE 4. PINK BOLLWORM INFESTATION DATA SHOWING NUMBER OF LARVAE RECOVERED PER GRAM OF BOLL AND PERCENTAGE OF BOLLS ESCAPING LARVAL DAMAGE, 1956

Cotton	Total bolls	Average boll weight, grams	Entrance holes per boll	Larvae recovered per gram of boll weight	Number of undamaged bolls	% bolls without larvae
Deltapine 15	56	15.8	2.00	.071	27	48.2
G. thurberi	117	0.6	0.16	.139	110	94.0
Texas 42	27	16.1	3.00	.129	11	40.7
Stoneville 2B	57	17.5	1.74	.054	32	56.1
G. tomentosum x 2B	18	2.7	0.11	.021	17	94.4
Z74275	12	2.8	0.33	.117	8	75.0
Naurotzky	61	17.8	2.00	.052	38	63.3

ed by the female moths. Chemical control by insecticides probably would be much more effective if eggs were deposited on exposed parts of the plants. The young larvae also would be more exposed to the elements and to their natural enemies, all of which might be important factors in reducing the number of larvae gaining entrance into the bolls. It was, therefore, necessary to make a detailed study of the oviposition sites and larval behavior (Brazzel and Martin, 1955, 1957). Previous work along these lines was reported by Busck (1917), Loftin (1921), Ohlendorf (1926) and Fenton and Owen (1953). In general, these workers found that the favored oviposition site was on green bolls and preferably beneath the calyces or boll involucres. During the early part of the season, before bolls have been formed, eggs are deposited indiscriminately over the plant. The work cited from this Station confirms these earlier reports.

A study of larval behavior indicated that many of the larvae which hatch from eggs deposited beneath the boll calyces enter the boll directly and do not move about over the plant. These larvae would be difficult to control by ordinary means. It also was found that the larvae are cannabalistic and will attack each other whenever they come in contact during their travels over the plant. Thus, a variety possessing characters which would influence the female moths to deposit eggs away from the bolls could serve as a desirable adjunct to chemical or biological control, or both.

Studies of the morphological characters of certain cottons revealed that they may have some influence on the oviposition sites selected by the pink bollworm. Studies along these lines were conducted during 1956-57. Six plants of each cotton were planted in each of the four large field cages. Squares were removed from the plants until September 1 to allow all species to begin fruiting together. Moth releases were begun when 10-day-old bolls were present. Five releases of 300 moths per cage were made in 1956 and three releases were made in 1957. Five days after each release, two plants selected at random from each species were examined under a binocular microscope for eggs.

Results of these tests are reported in Table 5. More than 50 percent of the eggs found on Deltapine 15 and *G. thurberi* in 1956 were deposited on the vegetative parts of the plants. On Pubsecent, more than 50 percent were found on the vegetative plant parts and the exposed boll areas. Most of the eggs on the other cottons were found under the boll calyces.

More eggs were found in 1957 on the vegetative parts of Pubsecent, Pima, *G. herbaceum* and *G. thurberi* than on the exposed boll areas or under the boll calyces. All the eggs found on *G. thurberi* were on vegetative parts. None of the cottons had as many eggs deposited under the boll calyces as on the other plant parts combined.

Some varieties apparently were more preferred by the ovipositing moths than others. *G. herbaceum* was significantly more attractive in 1956 than were the other varieties. Delta Smoothleaf was the most preferred variety in tests conducted in 1957. *G. thurberi* was the least preferred variety for oviposition during both years.

Additional research was conducted during 1957 on varietal preference. The same cottons were planted in the greenhouse. The plants were transferred to the field before bolls formed and each plant placed in a 2 x 2-foot cage. Two plants of each cotton were tested weekly for 9 weeks by confining 20 moths on each plant. A total of 18 plants were inspected for each variety or species. All records were made before bolls were present.

TABLE 5. RELATIVE PREFERENCE BY THE PINK BOLLWORM FOR OVIPOSITION SITES UPON CERTAIN VARIETIES AND SPECIES OF COTTON WHEN CONFINED IN LARGE FIELD CAGES WITH FRUITING PLANTS OF EACH

Species or variety	Number of eggs							
	1956				1957			
	Vegetative parts	Under calyx	Fruit area[1]	Total	Vegetative parts	Under calyx	Fruit area[1]	Total
Deltapine 15	301	143	91	535	1036	1045	202	2283
% of total	56.3	26.7	17.0	16.7[2]	45.4	45.8	8.8	19.4[2]
Delta Smoothleaf	18	113	2	133	1698	1554	566	3818
% of total	13.5	85.0	1.5	4.2[2]	44.5	40.7	14.8	32.5[2]
Pubsecent	78	163	149	390	1304	244	799	2347
% of total	20.0	41.8	38.2	12.1[2]	55.6	10.4	34.0	20.0[2]
Pima	167	662	10	839	1712	190	19	1921
% of total	19.9	78.9	1.2	26.1[2]	89.1	9.9	1.0	16.4[2]
G. herbaceum	111	1034	144	1289	627	259	94	980
% of total	8.6	80.2	11.2	40.1[2]	64.0	26.4	9.6	8.3[2]
G. thurberi	17	10	0	27	401	0	0	401
% of total	63.0	37.0	0	0.8[2]	100	0	0	3.4[2]
Total				3213				11750

[1]Indicates eggs found on bracts and exposed parts of the boll above the calyx.
[2]Expressed as a percentage of grand total egg production for the respective year.

TABLE 6. RELATIVE PREFERENCE OF OVIPOSITION SITES BY THE PINK BOLLWORM WHEN CONFINED ON A SINGLE VARIETY OR SPECIES OF COTTON BEFORE BOLLS WERE FORMED, 1957

Species or variety	Number of eggs				Total
	Terminals	Leaves	Axil buds	Stems	
Deltapine 15	196	321	274	0	791
% of total	24.8	40.6	34.6	0	
Delta Smoothleaf	210	321	430	0	961
% of total	21.9	33.4	44.7	0	
Pubsecent	112	354	78	112	656
% of total	17.1	53.9	11.9	17.1	
Pima	255	379	179	0	813
% of total	31.4	46.6	22.0	0	
G. herbaceum	314	151	304	0	769
% of total	40.8	19.6	39.6	0	
G. thurberi	76	87	152	0	315
% of total	24.1	27.6	48.3	0	

Table 6 indicates that, even in the absence of other varieties, pink bollworm moths will deposit relatively few eggs on *G. thurberi*. There was little difference in the number of eggs recorded on each of the other cottons. Axillary and terminal buds generally were the favored oviposition sites on all the cottons. However, on Pubsecent, 53.9 percent of the eggs were deposited on the hirsute (hairy) leaves and 17 percent on the stems.

Investigations to date indicate that certain cottons possess physiological or morphological characters which furnish some resistance to pink bollworm attack, either by a deleterious effect on developing larvae or by influencing the female moths to deposit most of their eggs on exposed plant parts. Some varieties also appear to be unattractive to the females. No variety possessing both resistance and desirable agronomic characters has been found, but results to date give promise of a such variety in the future.

CHEMICAL CONTROL

Chemical control of this pest has proved difficult since a large percentage of pink bollworm eggs are deposited under the boll calyces and many of the larvae enter the boll immediately after hatching and, thus, never come in contact with the insecticide. There also has been some question as to whether chemical control has been the result of larval or adult mortality.

TABLE 7. COMPARATIVE TOXICITY OF GUTHION AND DDT TO THE PINK BOLLWORM[1]

Pounds per acre	% Mortality	
	Guthion	DDT
4.0		55
2.0	81	48
1.0	64	19
0.5	45	

[1]Laboratory test where green bolls were infested with 5 eggs each. The bolls were sprayed and examined for larvae after 10 days. Forty to 50 bolls were used for each concentration.

Work at this Station in 1954 indicated that Guthion was more effective under laboratory conditions at the rate of 1.0 pound of actual toxicant per acre than DDT at 4.0 pounds (Ivy, *et al*, 1955). These results are reported in Table 7.

Tests with these two insecticides also were conducted in the field. Dust treatments of 10 and 20 percent DDT and 5 percent Guthion were compared with an untreated check on randomized plots of .10 acre. Each treatment was replicated four times. The dusts were applied at the rate of 15 pounds per acre. Applications were begun September 10 when 7 percent of the blooms were found rosetted. Six additional applications were made at approximately 5-day intervals. Boll weevil and bollworm populations were extremely low and were not considered factors affecting results of the experiment, which are reported in Table 8.

Plots treated with Guthion had significantly fewer injured bolls than the DDT-treated or check plots. There were no significant differences between the DDT and check plots, and no differences in grade or staple among the treatments or the check.

Subsequent cage tests were conducted to determine the efficiency of several organic insecticides in controlling the adult pink bollworm (Williams, *et al*, 1958). These experiments were designed to evaluate the insecticides according to their effect on mortality and oviposition of moths. Sprays prepared from emulsifiable concentrates of the following insecticides were tested: DDT, Guthion, toxaphene, dieldrin, endrin, malathion, parathion, aldrin, benzene hexachloride, heptachlor, toxaphene-DDT (2-1) mixture, dieldrin-DDT (1-2) mixture and Guthion-

TABLE 8. RESULTS OF FIELD TESTS WITH DDT AND GUTHION FOR THE CONTROL OF PINK BOLLWORM, 1954

Treatment	Date counted	% injured bolls	Number of worms per 100 bolls	Pounds of seed cotton per acre
Guthion	9/16	11.2	15.0	
	9/24	7.5	8.0	
	10/1	4.3	5.0	
	10/8	2.0	2.3	
	10/15	0.8	0.8	
	Average	5.2	6.2	994
DDT 20%	9/16	22.0	28.2	
	9/24	28.3	41.8	
	10/1	32.0	48.3	
	10/8	19.3	24.5	
	10/15	17.3	21.3	
	Average	23.8	32.8	852
DDT 10%	9/16	16.7	26.0	
	9/24	24.0	33.8	
	10/1	18.8	36.3	
	10/8	23.0	35.0	
	10/15	19.8	27.3	
	Average	20.5	31.7	900
Check	9/16	24.0	41.2	
	9/24	31.8	44.5	
	10/1	35.5	69.0	
	10/8	30.8	47.0	
	10/15	33.5	52.8	
	Average	31.1	50.9	919

DDT (1-3) mixture. Untreated checks were maintained for comparison.

The insecticides were applied as sprays to individual cotton plants growing in the field at the rate of 2½ gallons total spray per acre. Generally, nine replicate plants were sprayed with each dosage of insecticide. Ten pink bollworm moths were caged on each plant within 2 hours after the spray was applied.

After the moths had been confined on the treated plants for 5 days, the percentage of mortality was determined. The average number of eggs per moth was determined by examining each plant under a binocular microscope.

Results are presented in Table 9. Less endrin, Guthion, parathion, malathion and dieldrin were necessary to produce a mortality of 50 percent (LD 50) of the adults than DDT, while more toxaphene-DDT (2-1) mixture, dieldrin-DDT (1-2) mixture and heptachlor were required. Endrin and Guthion were the most toxic compounds at very low dosages.

An increase in dosage of any compound generally was accompanied by an increase in moth control and a decrease in egg production. Heptachlor was an exception since increased dosages did not cause reductions in oviposition, and applications at normal field dosages actually were accompanied by an increase in the number of eggs deposited per moth. When applied at normal field dosages, aldrin, benzene hexachloride and heptachlor were virtually ineffective in producing adult mortality and caused very little reduction in oviposition.

The greatest percentage control was obtained from Guthion applied at the rates of 0.25 and 0.50 pound of actual toxicant per acre, and from the Guthion-DDT (1-3) mixture applied at 2.0 pounds of active toxicant per acre. A drastic reduction in oviposition was obtained with these dosages. Endrin applied at rates of 0.25 and 0.50 pound actual toxicant per acre gave results comparable with the 2.0 and 3.0 pounds per acre rates of DDT.

These data are in agreement with earlier work by Robertson (1948) who reported results of experiments with DDT which indicated that control of the pink bollworm was accomplished by adult mortality and a consequent reduction in oviposition. With the exception of heptachlor, this appears to be true for all the compounds tested.

In addition to these tests, experiments also were conducted to determine the toxicity of several insecticides to eggs and larvae of the pink bollworm (Brazzel and Gaines, 1958).

For one series of tests, 1-day-old pink bollworm eggs were placed in groups of 10 each on 1 centimeter square tabs of paper. Known concentrations of each insecticide, prepared by dissolving the technical grade material in acetone, were applied by dropping approximately 25 microliters of each dilution onto the eggs. Each group of 10 eggs was considered to be one replication. Each test was replicated five times. Insecticides tested included DDT, toxaphene, dieldrin, endrin, lindane, heptachlor, malathion, parathion and Guthion.

Treated eggs were held for 5 days in vented containers. Mortality counts were made from the number of eggs that did not hatch during this period. Figure 8 indicates that Guthion and parathion were much more effective as ovicides than the other insecticides tested.

Apparently complete embryonic development occurred in the treated eggs that did not hatch since development appeared to progress up to a point just prior to when normal hatching could

TABLE 9. COMPARATIVE EFFECTIVENESS OF SEVERAL COMPOUNDS ON MORTALITY AND OVIPOSITION OF PINK BOLLWORM ADULTS

Material	Pounds technical per acre	Number moths treated	Eggs per moth on treated plants	% control	% reduction in oviposition
DDT	1	340	3.94	52.93	81.0
	2	350	2.37	59.75	89.0
	3	350	1.38	77.43	93.5
Guthion	1/32	90	2.75	33.58	87.0
	1/16	90	2.58	51.69	88.0
	1/8	50	3.51	66.45	83.0
	1/4	90	3.98	94.84	81.0
	1/2	90	0.13	88.68	99.0
	1	30	0.17	74.91	99.0
Toxaphene	1	90	9.51	29.42	55.0
	2	90	6.39	55.15	70.0
	4	90	3.56	75.53	83.0
Dieldrin	1/2	90	9.18	45.42	57.0
	1	90	3.68	68.91	83.0
	1½	80	7.09	75.43	66.5
Endrin	1/8	80	6.02	62.54	71.5
	1/4	90	2.90	85.51	86.0
	1/2	90	1.30	80.68	93.5
Malathion	1/4	90	10.03	41.64	53.0
	1/2	90	4.50	43.13	79.0
	3/4	80	5.83	60.36	72.0
Parathion	1/8	90	13.18	51.98	38.0
	1/4	90	7.31	48.31	65.5
	1/2	90	2.80	71.60	87.0
Aldrin	1/4	30	31.43	9.49	0.0
	1/2	90	12.59	23.95	40.0
	1	90	12.55	46.90	86.0
	2	60	3.00	73.89	86.0
Benzene hexachloride	1/4	20	26.00	00.00	0.0
	1/2	90	12.21	32.15	46.0
	1	80	8.58	40.61	59.5
	2	50	4.25	73.34	80.0
Heptachlor	1/4	30	7.30	27.62	65.5
	1/2	90	13.56	25.65	35.0
	1	90	18.11	38.35	14.0
	2	60	10.13	38.98	52.0
Toxaphene-DDT (4-2)	1	80	2.94	27.84	86.0
	2	90	5.45	36.99	71.0
	4	90	2.87	69.83	87.0
Dieldrin-DDT (1-2)	1	90	4.05	23.39	80.0
	2	90	1.39	54.66	93.0
	4	90	0.33	85.96	99.0
Guthion-DDT (1-3)	1/2	90	2.16	33.92	90.0
	1	90	0.72	62.98	97.0
	2	90	1.03	92.32	95.0
Check		670	21.13		

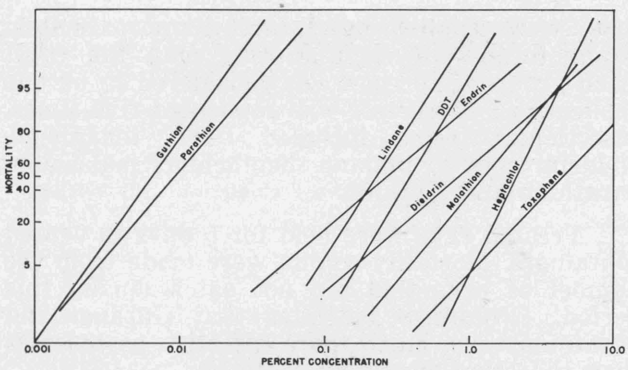

Figure 8. Dosage-mortality curves for pink bollworm eggs when treated with acetone solutions of several insecticides.

be expected. A comparison of the oxygen requirement of eggs treated with Guthion and DDT with untreated eggs confirmed this observation since death of the embryos in the treated eggs occurred within a few hours prior to hatching of the untreated eggs.

In a second series of tests, conducted in the greenhouse, 1-day-old pink bollworm eggs were placed on 10 to 20-day-old bolls. Batches of five eggs were placed at each of two locations beneath the boll calyces. All eggs were thus placed in protected sites. The infested plants were not treated until 3 days later. The average incubation period of eggs was 4 days. Thus, most of the eggs should have hatched within 12 hours of the insecticidal applications.

The plants were sprayed under a chamber at approximately 60 p.s.i Sprays were prepared from emulsifiable concentrates and were delivered at the rate of 7½ gallons of mixture per acre. Insecticides and rates of actual toxicant per acre are given in Table 10. All treatments were replicated six times.

The infested bolls were collected 10 days after spraying and examined under a binocular microscope. Records were made of the number of eggs that hatched and of the number and location of larvae per boll.

There were significant reductions in the numbers of eggs that hatched in the Guthion and parathion treatments when compared with the check, indicating the ovicidal action of these materials. Slight reductions in the percentages of eggs that hatched also were evident in the other insecticidal treatments when compared with the checks. These reductions were not significant.

All insecticides reduced significantly the number of larvae which entered the bolls when compared with the check. Guthion and DDT were the most outstanding materials in this respect. Calculation of the percentage of larvae entering the bolls was made by subtracting the number of larval entrance holes per boll from the total number of eggs that hatched per boll. This procedure was followed to keep ovicidal effect of the insecticides from complicating the results.

Only those larvae which attempted to enter the bolls above the calyces were killed by insecticides. However, approximately 75 percent of the larvae that gained entry into the untreated bolls did so above the calyces even though the eggs from which they emerged had been placed under the calyces. This suggests that even though large numbers of eggs are deposited in protected sites by the female moths, some degree of field control may be obtained from the mortality of the young larvae which wander out of these sites before attempting entry into the bolls.

Significantly fewer larvae were recovered from the insecticidal treatments than from the checks. Guthion and DDT also were the most effective insecticides in this respect.

Results of all the experiments cited indicate that Guthion and DDT were the most effective materials tested for pink bollworm control and that field control is accomplished by adult mortality, reduction in oviposition and the death of developing embryos and newly hatched larvae.

Recent experiments by the USDA Entomology Research Division with Sevin (1-napthyl-N-methyl carbamate) a new type insecticide, show that it is as effective as DDT for controlling pink bollworm infestations (Bottger, *et al*,

TABLE 10. EFFECTIVENESS OF SEVERAL INSECTICIDE SPRAYS FOR THE CONTROL OF PINK BOLLWORM EGGS AND LARVAE, COLLEGE STATION, 1956

Insecticide	Pounds technical per acre	Number of bolls tested	% eggs hatched	% larvae entered bolls	% larvae entered above and below calyx[1]	% larvae recovered	% control of larvae
DDT	1.5	90	66.1	20.2	44/56	15.1	70.5
Toxaphene	3.0	88	69.1	39.5	62/38	28.6	42.3
Dieldrin	0.3	81	70.5	44.9	71/29	32.8	34.5
Heptachlor	0.4	79	72.2	53.2	69/31	39.1	22.3
Endrin	0.4	75	69.3	39.9	70/30	28.9	41.8
BHC	0.3	80	65.8	41.3	71/29	31.0	39.7
Malathion	1.0	77	70.3	37.8	68/32	29.0	44.8
Parathion	0.25	75	60.9	32.1	69/31	22.1	53.1
Guthion	0.25	75	57.0	13.3	36/64	9.1	80.6
Check		72	79.6	68.5	75/25	51.5	

[1]First number represents the larvae that entered above the calyx; second figure, the larvae that entered below the calyx.

TABLE 11. AVERAGE PERCENTAGE OPEN BOLLS ON INDICATED DAY AFTER TREATMENT WITH PREHARVEST CHEMICALS AT COLLEGE STATION, 1955

Treatment[1]	% open bolls, days after treatment			
	−1	14	21	28
Check	64.6	65.4	78.6	90.4
Aminotriazole	59.4	83.0	87.0	95.4
Shed-A-Leaf	55.0	73.6	90.4	98.0
Pentachlorophenol	62.0	74.4	87.4	98.0

[1]Dosage rate per acre in Aminotriazole, 1 pound; Shed-A-Leaf, 1 gallon; Pentachlorophenol, 1 gallon.

1958). Cage tests indicated that 2.0 pounds of actual Sevin per acre resulted in 100 percent mortality of pink bollworm moths in 24 hours after application, as compared with 78 percent mortality for 2.0 pounds of DDT. The residual effect of Sevin appeared comparable with that of DDT.

In cage tests where first instar larvae were exposed to 2.0 pound dosages of actual Sevin and DDT per acre, Sevin caused reductions of 96 percent in mines and 95 percent in number of larvae per boll, as compared with a 64 percent reduction in mines and an 83 percent reduction in larvae per boll resulting from DDT.

Field experiments conducted near Brownsville in 1957 under conditions of severe pink bollworm and boll weevil infestations indicated gains of 1,680 pounds of seed cotton per acre from plots treated with Sevin, when compared with yields obtained from untreated check plots (Bottger, *et al*, 1958). Other tests by these investigators suggested that 5 and 10 percent Sevin dusts were equally as effective as Guthion-DDT and dieldrin-DDT mixtures for control of the pink bollworm. Yields obtained from these treatments were comparable and ranged up to 1,100 pounds of seed cotton per acre greater than those harvested from the untreated checks.

Defoliants

The use of the recommended preharvest chemicals listed in Texas Agricultural Extension L-145, "Cotton Defoliation Guide for Texas," will hasten the opening of mature bolls for earlier harvest and will delay build-up of pink bollworm infestations approximately 3 weeks following defoliation.

TABLE 12. AVERAGE NUMBER OF WORMS IN 50 BOLL SAMPLES FROM PLOTS RECEIVING PREHARVEST CHEMICALS AT COLLEGE STATION, 1955

Treatment[1]	Number of larvae, days after treatment				
	−1	14	21	28	35
Check	2.0	3.8	9.5	13.7	20.3
Aminotriazole	1.7	1.7	1.5	3.5	10.5
Shed-A-Leaf	4.7	3.0	2.3	2.2	10.2
Pentachlorophenol	1.0	3.5	2.3	1.8	13.8

[1]Dosage rates per acre: Aminotriazole, 1 gallon; Shed-A-Leaf and Pentachlorophenol, 1 gallon.

TABLE 13. EFFECT OF PREHARVEST CHEMICALS ON PINK BOLLWORM INFESTATION IN BRAZOS RIVER BOTTOMS, 1956[1]

Treatment[1]	Criterion	Weeks after treatment		
		2	3	4
Check	% infestation	90	100	100
	Mines per boll	3.3	5.0	10.0[2]
Shed-A-Leaf[3]	% infestation	32	36	60
	Mines per boll	1.0	1.2	1.4
Sodium arsenite[3]	% infestation	18	32	100
	Mines per boll	0.6	0.8	4.6[4]

[1]Average initial field infestation 1 week prior to treatment, 7 percent.
[2]Estimated loss due to infestation 10 percent.
[3]Dosage rates per acre: Shed-A-Leaf, 1 gallon; sodium arsenite, 1 gallon.
[4]Estimated loss due to infestation 1 percent.

The effect of preharvest chemicals on boll opening is shown in Table 11. Records taken at weekly intervals indicated that there was a greater number of open bolls in the treatments than in the check and that defoliation resulted in more bolls opening earlier.

The delay of build-up in infestation following defoliation, as indicated by the number of larvae found in 50-boll samples, is shown in Table 12. Samples were taken at random from the green bolls remaining in each plot. Bolls in the untreated plots were infested with approximately twice as many larvae as those in the defoliated plots at the end of the 35-day observation period.

A study of pink bollworm build-up in defoliated and non-defoliated cotton was conducted at eight locations in the Brazos River bottom during the summer of 1956. Defoliants were applied by airplane. Table 13 indicates that pink bollworm populations increased faster in the non-defoliated plots, with infestations reaching 100 percent within approximately 3 weeks. Generally, 5 to 6 weeks were required for infestations to reach the same level in the defoliated plots.

Since heavy rain frequently delays stalk destruction and plow-up after harvest, preharvest chemicals which inhibit regrowth are important factors in eliminating or reducing the food supply for late-season generations, and thus, can reduce the number of overwintering larvae. Table 14 indicates the effectiveness of certain chemicals in inhibiting regrowth.

TABLE 14. AVERAGE EFFECT OF THE INDICATED PREHARVEST CHEMICALS ON THE FOLIAGE OF COTTON PLANTS AT COLLEGE STATION, 1955

Material[1]	% regrowth[2]
Check	61.2
Shed-A-Leaf	23.2
Aminotriazole	30.4
Pentachlorophenol	23.2

[1]Dosage rates per acre: Shed-A-Leaf, 1 gallon; Aminotriazole, 1 pound; Penthachlorophenol, 1 gallon.
[2]Expressed as percentage recovery of original number of green leaves 21 days after treatment.

TABLE 15. RESULTS OF NOZZLE TEST, COLLEGE STATION, 1954-55

Treatment	Nozzles per row	Gallons per acre	1954			1955		
			Number of larvae per 100 bolls	% injured bolls	Pounds of seed cotton per acre	Average number of mines per 100 bolls	% injured bolls	Pounds of seed cotton per acre
Check	0	0	307	80	735	70	85[1]	1364
Dust	1	15[2]	153	57	805	53	54	1444
Dust	2	15[2]	174	64	795	25	32	1402
Spray	3	6	137	52	718	19	28	1400
Spray	3	9	175	61	732	29	41	1324
Spray	3	18	153	51	740	26	35	1310
Spray	5	10	215	61	732	22	31	1384
Spray	5	15	177	58	725	29	34	1484
Spray	5	30	147	52	820	20	30	1370

[1]In 1955, check plots were treated with 0.4 pound of endrin per acre on a 5-day schedule.
[2]Pounds of dust applied per acre.

From the data presented, it is evident that defoliation can play an important role in pink bollworm control programs by delaying the build-up of heavy infestations late in the season, and thus reducing the number of potential over-wintering insects.

Nozzle Arrangements

Work was conducted at this Station for several years to determine the most effective nozzle arrangements and gallonage for obtaining cotton insect control with ground sprayers. Previous work indicated that one hollow-cone nozzle per row calibrated to deliver 2 gallons of total material per acre was as effective as two or three nozzles per row calibrated to deliver up to 14 gallons of spray per acre (Brown and Hanna, 1954; Smith and Hanna, 1955; and Smith, *et al*, 1956). Experience shows that best results in the field may be obtained by spacing cone-type nozzles every 20 inches on the sprayer boom, as recommended in Texas Agricultural Extension Service L-128, "Texas Guide for Controlling Cotton Insects, 1958."

Results of additional tests of various nozzle arrangements and gallonages per acre under conditions of pink bollworm infestations are reported in Table 15 and 16 (Magee and Davenport, 1958). All plots, except the checks, were treated with a dieldrin-DDT (1-6) mixture at the recommended rates. Applications were made weekly in the 1954-55 tests, and at 5-day intervals in 1956. Spray applications were made with a high clearance, self-propelled sprayer. Dusts were applied with rotary hand guns at the rate of 15 pounds per acre. Infestation records for the boll weevil and bollworm were determined by square and boll examinations. Infestations of pink bollworm were measured by boll dissection in 1954-55 and by moth emergence from boll samples in 1956.

The 1954-55 tests indicate that in yields per acre, the three-nozzle-per-row spray arrangement calibrated to deliver 6 gallons per acre was as effective as any of the more complicated arrangements in the tests. Spray and dust treatments were about equally effective, and there was little difference among any of the treatments.

Work in 1956 was expanded to include wide-swath, jet-type nozzles. The jet nozzle arrangements consisted of one nozzle which was used to cover swaths up to 40 feet in width. One cone nozzle per row was as effective as any of the

TABLE 16. RESULTS OF NOZZLE TEST, COLLEGE STATION, 1956

Treatment	Nozzles per row	Gallons of spray per acre	% weevil punctured squares	% bollworm injured squares	Number of rosetted blooms per acre	Number of worms per 100 bolls	Pounds of seed cotton per acre
Spray[1]	1	6	3	5	704	0.1	2200
Spray[2]	3	6	1	4	1064	0.0	2225
Spray[3]	2	4	4	4	1604	0.2	2255
Spray[3]	2	6	22	7	1470	1.0	2012
Spray[1]	1	2	4	3	1666	1.4	2275
Spray[4]		11	14	8	1140	11.2	1988
Spray[5]		11	33	7	1844	15.6	1695
Untreated check			34	14	1695	11.1	1145
Pink bollworm check[2,6]	2	6	8	7	1154	17.4	2000

[1]Nozzles spaced 40 inches apart on sprayer boom.
[2]One nozzle directly over row and one on each side of row on drops.
[3]Nozzles spaced 20 inches apart on sprayer boom.
[4]2 wide-swath jet nozzles per 40-foot swath (fieldjets).
[5]1 wide-swath jet nozzle per 40-foot swath (boomjet).
[6]Sprayed with 0.4 pound of endrin per acre on 5-day schedule.

TABLE 17. MACHINE EFFICIENCIES BASED ON THE PERCENTAGE OF PINK BOLLWORM REDUCTION FOR SEVERAL TYPICAL TYPES OF MACHINES TESTED

Machines	% reduction					
	1953	1954	1955	1956	1957	Average
1. Standard shredders	51.1[1]		34.6	90.2		55.2
2. Modified commercial shredder		75.4		98.5		86.9
3. Experimental stripper-crusher-1		17.3				17.3
4. Experimental stripper-crusher-2			85.1	98.4		91.8
5. Ensilage harvester-1		60.3	71.5	97.5		76.3
6. Ensilage harvester-2				97.5	96.7	97.1
Average number of moths per 1/250-acre plot	344	469	714	33	665	

[1]Average of four stalk shredders.

more elaborate arrangements. The jet-type nozzles were not as effective as the cone-type nozzle arrangements.

CULTURAL AND MECHANICAL CONTROL

Even with the advent of the newer insecticides, practical pink bollworm control still is dependent mainly on cultural practices. Certain measures, such as regulated planting, stalk destruction and plowing under of crop debris, still are in use and are very effective for reducing pink bollworm populations. Machinery has an important function in the present day fight against the pink bollworm. Research at this Station on cultural and mechanical control of the pink bollworm has been centered around developing power-operated stalk-cutter shredders which would efficiently destroy over-wintering larvae harbored by the cotton residue left in the field.

Stalk Shredders

Twenty machines, including commercially manufactured shredders, modified shredders and several experimental machines, were tested to evaluate their effectiveness in reducing the populations of wintering larvae left in infested cotton.

Tests were located in fields which had suffered severe pink bollworm infestations during the growing season. Infestation records were determined by comparing the number of moths which emerged from crop residue collected before and after shredding. The crop residue consisted of bolls left on the stalks after harvest and of cotton waste which had fallen on the ground. The residue from each plot was collected and maintained separately in special emergence cages stored in a constant temperature room. Records of the number of moths emerging from the infested material were made at regular intervals until emergence ceased. The machines were evaluated according to the percentage reduction of pink bollworms.

Results of the tests are presented in Table 17. Four commercially manufactured power-operated stalk-shredders were tested in 1953. These machines were constructed in the same manner using a vertical shaft with horizontal rotating blades. The reduction of pink bollworms ranged from 36.4 to 69.4 percent, with an average of 51.1 percent. Various modifications, such as increasing the blade speed, use of cross blades, closer spacings on the discharge grill and the use of an impact blower at the discharge opening, were used on machines tested during 1954. The results were generally improved, but the extra power requirements caused by these modifications were beyond an economical range. Close observations during the operation of the standard shredders revealed that one of the reasons for inefficiency in the machines was due to the inability of the machines to pick up loose boll material from the ground. Much boll material was shattered by the machines passing over the stalks and by the shattering of the stalks from the impact of the blades.

A modified lift-type blade, Figure 9, in combination with a discharge grill used in a conventional shredder (machine 2, Table 15), increased shreddability and gave better insect control with only a slight increase in power requirement. The suction created by the whirling blades picked up boll material from the ground which ordinarily was missed with conventional straight blades.

A stripper-crusher unit was designed and constructed in an attempt to strip and crush the residue from standing cotton stalks prior to cutting with a stalk shredder. The first unit con-

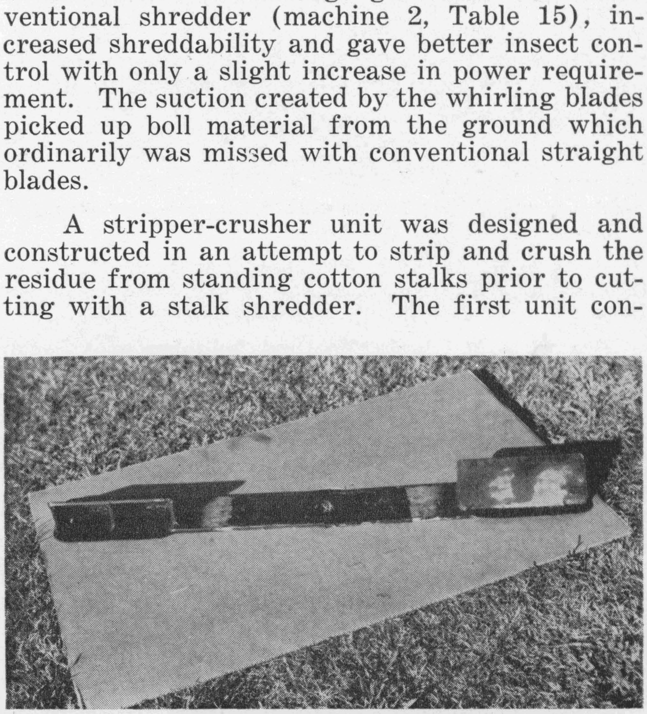

Figure 9. Modified lift-type blade used on machine 2, Table 15.

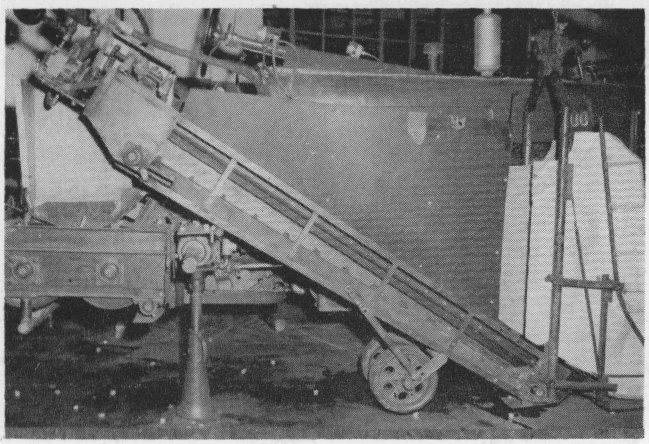

Figure 10. Stripper unit and crusher rolls used on machine 4, Table 15.

structed (Figure 10) used double steel stripper rolls and a pair of 6-inch (outside diameter) steel rollers to crush the stripped material. This machine was included in tests conducted in 1954, but, as shown in Table 15, its efficiency was very low. The steel stripper rolls were replaced with rubber-flighted stripper rolls and the crusher rolls were replaced with rubber-covered 13-inch (outside diameter) crusher rolls. These modifications improved the efficiency considerably, as shown in tests conducted in 1955-56.

Two ensilage harvesters also were included in these tests. Machine No. 5 in Table 5 used a cutting mechanism similar to a conventional stalk-shredder in that the cutting blades rotated in a horizontal plane on a vertical shaft. The housing was enclosed completely and the cut material was discharged through a wagon spout at the rear. The second harvester used a horizontal shaft with vertical rotating curved-type knives. Both machines required more power, but were superior to the standard shredders in reducing insect infestations.

LITERATURE CITED

Anonymous. 1954. The pink bollworm—how we fight it. USDA Leaf. 339. 8p.

Bottger, G. T., A. J. Chapman, Rex L. McGarr and C. A. Richmond. 1958. Laboratory and field tests with Sevin against cotton insects. Jour. Econ. Ent. 51(2):236-9.

Brazzel, J. R. 1955. The pink bollworm as a factor in cotton boll rots. Plant. Dis. Reptr. 39(7):583-84.

Brazzel, J. R. and J. C. Gaines. 1956. The effect of pink bollworm infestations on yield and quality of cotton. Jour. Econ. Ent. 49(6):852-54.

Brazzel, J. R. and J. C. Gaines. 1957. Cotton yield and quality losses caused by various levels of pink bollworm infestations. Jour. Econ. Ent. 50:609.

Brazzel, J. R. and J. C. Gaines. 1958. The toxicity of several insecticides to eggs and larvae of the pink bollworm. In Press.

Brazzell, J. R. and D. F. Martin. 1955. Behavior of pink bollworm larvae. Jour. Econ. Ent. 48(6):678-79.

Brazzell, J. R. and D. F. Martin. 1956. Resistance of cotton to pink bollworm damage. Tex. Agr. Exp. Sta. Bul. 843. 20p.

Brazzel, J. R. and D. F. Martin. 1957. Oviposition sites of the pink bollworm on the cotton plant. Jour. Econ. Ent. 50:122.

Brazzel, J. R. and D. F. Martin. 1958. Survival of long cycle pink bollworm in the College Station, Texas, area. (In Press).

Brown, E. C. Jr. and R. L. Hanna. 1954. Amount of spray per acre for the control of cotton boll weevils and bollworms. Tex. Agr. Exp. Sta. Prog. Rept. 1687. 5p.

Busck, A. 1917. The pink bollworm, Pectinophora gossypiella. Jour. Agric. Res. 9-347-70.

Chapman, A. J. and M. H. Hughes. 1941. Factors influencing the formation of resting pink bollworm larvae. Jour. Econ. Ent. 34(4):493-94.

Fenton, F. A. 1928. Biological notes on the pink bollworm in Texas. 4th Internat'l Cong. Ent. 2:439-47.

Fenton, F. A. and W. L. Owen. 1931. Hibernation of Pectinophora gossypiella in Texas. Jour. Econ. Ent. 24(6):1197-1207.

Fenton, F. A. and W. L. Owen. 1953. The pink bollworm of cotton in Texas. Tex. Agr. Exp. Sta. Misc. Publ. 100. 38p.

Fife, L. C. 1956. Seasonal occurrence of resting larvae of the pink bollworm in Central Texas. Jour. Econ. Ent. 49(4):562-53.

Fife, L. C., C. B. Cowan, Jr. and J. W. Davis. 1957. Factors influencing pink bollworm winter carryover in Central Texas. Jour. Econ. Ent. 50(5):642-44.

Ivy, E. E., J. R. Brazzel, A. L. Scales and D. F. Martin. 1955. Five new phosphate insecticides for cotton insect control. Jour. Econ. Ent. 48(3):293-95.

Loftin, V. C., K. B. McKinney and W. K. Hanson. 1921. Report on investigations of the pink bollworm of cotton in Mexico. USDA Bul. 918. 64p.

Lukefahr, M. and J. A. Griffin. 1956. The effects of food on the longevity and fecundity of pink bollworm moths. Jour. Econ. Ent. 49(6):876-77.

Lukefahr, M. and J. Griffin. 1957. Mating and oviposition habits of the pink bollworm moth. Jour. Econ. Ent. 50(4):487-90.

Magee, W. J. and M. G. Davenport. 1958. The effect of spray nozzle arrangement and gallonage on control of the pink bollworm and other cotton insects. In Press.

Noble, L. W. 1955. Investigations of the pink bollworm and hemipterous cotton insects. USDA Circ. 957. 15p.

Ohlendorf, W. 1926. Studies of the pink bollworm in Mexico. USDA Bul. 1374. 64p.

Owen, W. L. and S. L. Calhoun. 1932. Biology of the pink bollworm at Presido, Texas. Jour. Econ. Ent. 25(4): 744-51.

Robertson, O. T. 1948. Tests with DDT, benzene hexachloride and ryania for pink bollworm control. Jour. Econ. Ent. 41(1):120-1.

Smith, H. P. and R. H. Hanna. 1955. Effects of the type and arrangement of spray nozzle on the control of the cotton bollworm and boll weevil. Tex. Agr. Exp. Sta. Prog. Rept. 1752. 3p.

Smith, H. P., C. M. Hohn and R. L. Hanna. 1956. Effects of spray nozzle types and arrangements on cotton insect control. Tex. Agr. Exp. Sta. Prog. Rept. 1906. 2p.

Williams, R. K., J. R. Brazzel and D. F. Martin. 1958. The effect of certain organic insecticides on the mortality and oviposition of pink bollworm moths. Jour. Econ. Ent. 51(5):567-70.